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ABSTRACT

The level of carbon dioxide in a classroom can have a significant negative effect on teaching and learning. Carbon dioxide (CO2) level is affected by class size and time of day. Six urban schools were studied to characterize the effects of these three factors on different class sizes. Carbon monoxide, CO2, temperature, and relative humidity readings were taken in 32 rooms in 6 buildings at approximately 90-minute intervals during the school day. Statistical analyses show a steady increase in CO2 levels with time. Class-size and time-of-day effects are evident. All classes started approximately the same (600-700 parts per million [PPM]), but by day's end, the average CO2 level for small classes was 2,836 PPM and the average for larger classes was 4,181 PPM. Study results show a direct relationship between the amount of cubic feet of air per student and classroom performance of both students and teachers. Given the deteriorating condition of many schools, the increasing numbers of students, more reports of "sick building syndrome," increasing child asthma, and claims of low test scores, these results are important in matters of school health policy and practice. This report concludes with tables and appendices providing raw data and supplementary information on indoor air quality (IAQ). (RT)

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SERENDIPITOUS POLICY IMPLICATIONS FROM CLASS-SIZE-INITIATED INQUIRY: IAQ? *

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Serendipitous Policy Implications from Class-Size-Initiated Inquiry: IAQ?

ABSTRACT

Much Research Starts From Clinical Observation: Observations in Small (S, 15-17 students) and Regular (R, 20-28 students) classes, in the same building on the same day, revealed different behavior patterns. As the day wore on in (R) classes teachers became irritable, edgy, and tired. They wiped their eyes, sat down, and slowed or regimented instruction, often neglecting student indiscipline, lassitude, and off-task misbehavior. All occupants seemed hassled. In (S) classes teachers remained full of energy all day. Time-on-task stayed high and constant with students remaining well behaved, engaged, and energetic. Student and teacher behaviors were reciprocal, but positive. Upon hearing these scenarios, a graduate engineer said: "Check the carbon dioxide (CO_2) levels." CO_2 is related to the number of persons in a space, is cumulative, and causes drowsiness and lethargy that may influence teaching and learning. Class size and time of day seemed to be key variables.

The Study: An urban school district cooperated. Schools (n=6) were selected because a) they contained both (R) and (S) classes, b) they had the same type of Heating-Ventilating/Air Conditioning (HVAC) systems, and c) principals volunteered. A scientific instrument (Q-Trac) that took four readings simultaneously (CO, CO_2, Temperature, Relative Humidity) was calibrated to check Indoor Air Quality (IAQ). Readings were taken in 32 rooms in 6 buildings at approximately 8:00, 9:30, 11:00, 12:30, 2:00, and 3:30 (± 10 minutes). This study reports only CO_2 readings over six times in a day by the class size of (S) vs (R), and cubic feet (ft^3) per student.

Results: Analyses (t-tests, correlations, regressions) used (S) classes of n=17 or fewer vs (R) classes of n=19 or more and average CO_2 readings taken at six times a day. Readings of 1200 or more parts per million (PPM) of CO_2 get the attention of OSHA as unhealthy. The Q-Trac "maxed out" at 6000 PPM, and some (R) classrooms exceeded that. Class-size and time-of-day effects are evident. All classes start approximately the same (600-700 PPM) but by day's end the (S) average (2836 PPM), although high, is 1345 PPM ($p < .007$) below the (R) average at 4181 PPM.

Discussion: The study helped explain observed classroom behavior, [e.g., superiority of test scores and time on task from (S) students when compared to (R) students, better student engagement in (S) vs (R) class or the higher teacher energy levels in (S) vs (R) classes]. The key issue (shown in subsequent analyses) is cubic feet per student. Interactions of four IAQ variables are important relative to class size and cubic feet/student with implications for student achievement, behavior, and occupant safety. Given the deteriorating condition of many U. S. schools, the increasing numbers of students and of (S) classes in elementary grades, more reports of "sick building syndrome" increasing child asthma, and claims of low test scores, the policy, practice and health applications of results like these are important.

Serendipitous Policy Implications from Class-Size-Initiated Inquiry *

Introduction

The present research was initiated because of a series of observations in elementary classrooms (K-3) that were classified as Small (S) classes of about 15-17 students, and Regular (R) classes of about 20-28 students. The observations were part of the long-term research connected to and resulting from the Student Teacher Achievement Ratio (STAR) experiment, 1985-1989 in Tennessee and the series of STAR follow-up studies, 1989-2001.

The STAR study provided an extraordinarily rich data base of 11,601 students in 79 (later 76) schools in 49 districts. Approximately 1340 teachers and 450 teacher aides participated, 1985-1989. Using an in-school design, students and teachers were randomly assigned to class types (Small, or S; Regular or R; Regular-with Aide, or RA). Students moved as cohorts through K-3, but new teachers were assigned at random each year, as were new students who joined the study through mobility or retention in grade. Because STAR generated so many related studies, those involved in the original experiment have begun to consider STAR not as one study, but as a constellation of studies. Table 1 presents a partial listing of some of the many STAR-related studies. The current study will add one more area of inquiry to the list in a new category, school and learning environment facts, and specifically in the area of Indoor Air Quality (IAQ).

Because STAR and its results have been widely reported in the research and popular media, rather than repeating that information here we have included Appendices A and B which provide a) a summary of STAR's processes, and b) a summary of STAR results about the impact of small classes in early primary grades on student achievement, growth and development. Please refer to those brief appendices to get the summary information. The following narrative catches up the observations that initiated the original study.

Table 1 ABOUT HERE

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Table 1. Samples of the STAR Legacy of Class-size Studies, Categorized as "Subsidiary" (directly from STAR), "Ancillary" (building on the STAR database) and "Related" (usually involving STAR researchers and using STAR information and earlier findings).

CATEGORY, TITLE & PURPOSE *	DATE(S)	AUTHOR(S), SOURCE, DATE
STAR Pilot (DuPont)	1984-1986	Bain et al.
STAR (Class-size experiment)	1985-1989	Word et al., 1990 Finn & Achilles, 1990
Subsidiary Studies		
• Lasting Benefits Study (LBS)	1989-1996	Nye et al., 1991-1999
• Project Challenge (TN)	1989-1996	Nye et al., 1991-1995
• Participation, Grades 4, 8	1990, 1996	Finn, 1989, 1993; Voelkl, 1995; Finn et al., 1989; Finn & Cox, 1992
• STAR Follow-up Studies	1996-2000	HEROS, 1997-2000
Ancillary Studies		
• Retention in Grade	1994-1995	Harvey, 1994, 1995
• Achievement Gap	1993-1995	Bingham, 1993, 1994; Achilles et al., 1997-98
• Value of K in Classes of Varying Sizes (test scores)	1985-1989	Achilles, Bain, Nye, 1994
• School Size and Class-Size Issues	1985-1989	Nye, K., 1995
• Random v. Non-Random Pupil Assignment and Achievement	1985-1989	Zaharias et al., 1995
• Re-analysis, Sample "drift" (out-of-range classes)	1985-1989	Boyd-Zaharias et al., 1995 Finn et al., 1999
• Class Size and Discipline Grades 3,5,7	1989, 1991, etc. 1996	Several studies. SSS, 1995; Hibbs (1997).
• Outstanding Teacher Analysis (top 10% of STAR teachers)	1985-1989	Bain et al., 1992
• Teacher Aides (continuing)		Achilles et al., 1994; Gerber; Zaharias & Bain, 1998
• Continuing student growth	1985-2000	Finn, Achilles et al.; Bain et al.
• College entrance exams	2000	Krueger & Whitmore
Related Studies		
• Success Starts Small (SSS): A Study in 1:14 and 1:23 Schools	1993-1995	Achilles et al., 1994 Kiser-Kling, 1995
• Burke Co., NC Study	1992-2000	Achilles et al., 1995 SERVE, 1996 ; Harman et al., 1998
• Education Production Functions	1996-2000	Krueger, 1997, 1998, 1999, 2000

* This is a sample of STAR-related class-size studies. Not all authors appear exactly as listed here. A similar table appears in several STAR reports and articles. Others have reported on STAR (e.g., Mosteller, 1995; Finn, 1998; McRobbie et al., 1998); several have conducted secondary re-analyses of STAR data (e.g., Goldstein & Blatchford, 1998; Krueger, 1997-2000).

Much Research Starts From a Clinical Observation

In observing teachers and students in (S) and (R) classes, often in the same building and throughout the same day, a pattern of teacher and student behaviors and observer sensory perceptions began to emerge. In the (R) classes, the typical pattern showed a good start in the morning, but noticeable changes as the day wore on: teachers became irritable, edgy, and then portrayed an evident lassitude, if not tiredness. They often wiped their eyes, sat down, and otherwise slowed or regimented instruction, often neglecting to attend to minor student indiscipline and off-task misbehaviors.

As the day progressed, students increasingly showed signs of weariness—heads down, wiping their eyes, and often drifted off task, asked to leave the room, went to sleep, or acted out. Student and teacher behaviors were reciprocal and counter to a good learning environment.

In contrast, in (S) classes teachers seemed full of energy all day long. They often reported something like "I'm working harder each day but I'm not as tired as (last year in a larger class) and I'm enjoying teaching more." Time-on-task stayed constant and high throughout the day with students remaining well behaved, engaged, and energetic. Again, student and teacher behaviors were reciprocal and generally supported a strong climate conducive to learning.

The Study

A discussion of these observations with a graduate engineer elicited this response: "Check the carbon dioxide levels." The engineer explained that CO_2 is related to the number of persons in a space, is cumulative unless well ventilated, and causes both drowsiness and lethargy that could result in low attentiveness that would be detrimental to teaching and learning. Class size, the number of students in the defined space, seemed to be a key variable, as was time of day. This translated into cubic feet (ft^3) of space per students.

Permission was obtained to conduct a class-size/CO_2 study in an urban school district. Schools for study (n=6) were selected because a) they contained both (R) and (S) classes, b) they all had the same type of Heating-Ventilating/Air Conditioning (HVAC) systems, and c) principals volunteered.

A scientific instrument (Q-Trac) that took four readings simultaneously (Carbon Monoxide, or CO, CO_2, Temperature, and Relative Humidity or RH) was calibrated for the location. Two researchers conducted a pilot study in two facilities to determine feasibility, the best method for data collection, how much distraction the readings would cause, and to develop a scheme to record classroom context data.

During two weeks (November, 1999) readings were taken in 32 rooms in 6 buildings at approximately 8:00, 9:30, 11:00, 12:30, 2:00, and 3:30 (± 10 minutes). The reported data were the average of readings taken in 4 locations in each classroom at each time. Although data were obtained on all 4 Indoor Air Quality (IAQ) measures (CO, CO_2, Temperature, and Relative Humidity or RH) this portion of the study reports only on the CO_2 readings over the six times in a day by the class size of (S) vs (R).

Results: The Raw Data and Correlations

Appendix C contains the raw data (averages) readings from the Q-Trac at six times during the day, from 8:00 AM to 3:30 PM. Buildings are designated by capital letters (A, B, C, D, E, F) and rooms are identified by numerals. The designation A-1 is building A, room number one, etc. The study occurred in six buildings with a total of 32 rooms. Basic analyses for this report excluded building E, a private school of eighth grade only and no large classes. Building E data are represented in the basic correlation matrix shown as Table 2. In Table 2, the critical value $p \leq .05$ is .349 (.35). All complete data rooms($n=31$) are used in the correlations. In the next section, data are disaggregated to allow analyses based on class size, on cubic feet of space in a room per student, and finally by class size within the same building.

TABLE 2 ABOUT HERE

Results: Class-Size Analyses

Results of the class-size analyses used (S) classes of n=17 or fewer vs (R) classes of n=19 or more. Besides the t-tests reported here in Figures 1-4, researchers used correlations and some regressions. Note that readings of 1200 or more parts per million (PPM) of CO_2 would get the attention of OSHA as unhealthy. (Readings shown are averages; the Q-Trac "maxed out" at 6000 PPM, and some classrooms exceeded that reading). Class-size and time-of-day effects are plainly visible in each Figure. All rooms start approximately the same (600-700 PPM) but by day's end the (S) average (2836 PPM), although high, is 1345 PPM ($p < .007$) below the (R) average at 4181 PPM.

FIGURE 1 ABOUT HERE

The study helped explain observed classroom outcomes and behavior, [e.g., superior test scores, and greater time on task, student engagement, and teacher energy levels in (S) vs (R) classes]. Interactions of four IAQ variables are important relative to class size with implications for student achievement, behavior, and occupant health and safety. This first analysis pointed to CO_2 and cubic feet (ft^3)/student as a key issue.

Results: Cubic Feet (ft^3)/Student and CO_2 Analyses.

Although all analyses in this study portrayed problems with CO_2 in school settings, the analysis that used rooms with large ft^3/student vs rooms with small ft^3 showed the issue dramatically. This analysis used five schools with 27 separate classrooms where six measures were taken throughout the day. One school (5 classrooms) was excluded from this analysis because a) it had only grade-8 students and other schools had mostly K-4 students, b) it was a private school with 10-15 students/room, and c) two of the rooms were "outliers" with 1895 and 2842 ft^3/student while no other rooms exceeded 1305 ft^3/student (range = 284-1305 ft^3/students) with an average of 536 ft^3/student.

Results (Figure 2) show that at 8:00 AM the two groups of classrooms (large ft^3/student n=13 and small ft^3/student n = 14) had nearly equal PPM of CO_2 (648.8 v. 644.2) By 9:30 AM, the second reading, the differences between large and small ft^3/student had reached $p \leq .03$, and by the end of the school day the differences were significant at $p \leq .003$. The large ft^3/student rooms were unhealthy at 2758 CO_2 PPM, but the small ft^3/student rooms were stifling at an average of 4053 PPM of CO_2, more than 3 times what OSHA would allow for adults. Young

children, with sensitive and not fully developed cardiovascular systems are in these poor IAQ rooms by compulsory-attendance laws.

FIGURE 2 ABOUT HERE

Class Size Within-Schools Analyses

Using (S, n=13) and (R, n=14) classes within the same school produced the results in Figure 3. This analysis clearly shows the class-size and ft^3/student influences with (S) classes showing major IAQ advantages over (R) classes by almost 1500 PPM CO_2.

FIGURE 3 ABOUT HERE

Suggestions

- Schools should be monitored for signs of poor environment, initially by observing occupant behavior.
- Specific IAQ guidelines need to be developed for schools.
- Facilities should be checked periodically for IAQ.
- School construction specifications should include cubic feet/student, not just square feet/student.
- Additional research should test connections between IAQ and student learning, occupant health, and behaviors.

Serendipity

Although the study was initiated to help explain observed classroom behavior, the measured superiority of test scores and of time on task from (S) students when compared to (R) students, the observed better student engagement in (S) vs (R) class or the higher teacher energy levels in (S) vs (R) classes, the key issue (shown in subsequent analyses) is cubic feet per student. Interactions of the four IAQ variables are also important relative to class size and cubic feet/student.

Significance

America is experiencing a dramatic deterioration of facilities as shown by such things as the GAO report of $212 billion just to get buildings up to code; Children in America's' Schools video; Savage Inequalities (Kozol). The "Energy Crisis" of the 1970's caused educators to "tighten" schools so they must rely almost exclusively on HVAC systems that are installed by the low bidder. Enrollment increases often bring expansions. Most building specifications describe the square-foot requirements, but people are three-dimensional. Health conditions, especially the increase in asthma for inner-city African-American youth (in decaying facilities)

and the numbing effects of short-term irritations of excess CO_2 may be directly connected to IAQ—and (as we hope to show in further studies) so may some test-score results. (Students are often tested in closed rooms for quiet). Interesting speculation.

The initial observations in smaller and larger classes did lead to interesting speculations. This one brief test shows that a possible reason that students in smaller classes outperform students in larger classes is that the IAQ in smaller classes is better than IAQ in larger classes. A review of the correlations in Table 2 will show that small classes have other advantages within the four variables in this study.

Policy implications

Educators and architects need to review facilities "specs," adjusting for "tight" buildings and the cubic—not square—foot requirement of education and students. The GAO estimate to fix America's schools may be way low. And, of course, small classes can't be the only answer, because they will require more space.

Concluding Comments.

Given the deteriorating condition of many U. S. schools, the increasing numbers of students and of (S) classes in elementary grades, more reports of "sick building syndrome," increasing childhood asthma, low test scores, and needs for new and remodeled schools, the policy and practice applications of these results are important. The IAQ in this sample of America's schools not only was very unhealthy, but it seemed to influence teaching and learning negatively. (This seems to border upon enforced child abuse). Information about IAQ appears in Appendix D, and IAQ is beginning to gain some national interest, especially as Americans review the poor quality of many schools, the increases in child asthma, and episodes of the sick building syndrome.

Even in casual observations, the stale air in many rooms troubles students, teachers, and others. The obvious positive student behaviors and increase outcomes in small classes may have connections to class size in the school rooms themselves. Areas for future research seem bounded only by the researchers' tools, imaginations, and tolerance for poor environment.

NOTE: Class-size researchers continue to seek to explain why small-class students achieve and behave well. This study suggests an important intersection among school environment, class size, and school modernization needs. These results need to be replicated and expanded, but even as presented they have a key message about the effects of the schooling environment on health and behavior of teachers and students and on student achievement. The study was conducted by Jean Prout, EdD, with the help and advice of C. M. Achilles, EdD (class size), G. C. Bobbett, EdD (data analysis), and M. McEvoy EdD (environmental engineering).

References

Achilles, C. M. (1999). Let's put kids first, finally: Getting class size right. Thousand Oaks, CA: Corwin.

Achilles, C. M., Finn, J. D. et al. (2000, December). The varieties of small classes and their outcomes. Paper prepared for the conference, "Taking small classes one step further." Sponsored jointly by the Laboratory for Student Success (LSS) at Temple University's Center for Research in Human Development and Education (CRHDE) and the U. S. Department of Education, Washington, DC: 11/30-12/1, 2000.

Hayden, P., with K. Cauthen (1996). Children in America's schools. Portions narrated by Bill Moyers. Corporation for Public Broadcasting. A co-production of the Saint/Hayden Co. and South Carolina ETV.

Kozol, J. (1992). Savage Inequalities. New York: Harper Collins.

Prout, J, (2000). Indoor air quality: Multiple implcations of carbon dioxide (CO2) in the classroom. Unpublished EdD Dissertation, Ypsilanti, MI: Eastern Michigan University.

Word, E., Johnston, J., Bain, H., Fulton, B., Zaharias, J., Lintz, N., Achilles, C. M., Folger, J., & Breda, C. (1990). Student/teacher achievement ratio (STAR): Tennessee's K-3 class size study. Final report and final report summary. Nashville, TN: Tennessee State Department of Education.

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Table 2. Inter-correlations of Four IAQ Variables: Carbon Monoxide (CaMo), CO2, Rel. Humidity (RH)., and Temperature (T).

Correlation Matrix p.05 = .349

	Cft/Student	Cub-Ft	No. Students	CO2/800	CO2/930	CO2/1100	CO2/1230	CO2/200	CO2/330	CaMo/800	CaMo/930	CaMo/1100	CaMo/1230	CaMo/200	CaMo/330	RH1/800	RH/930	RH/1100	RH/1230	RH/200	RH/300	T/800	T/930	T/1100	T/1230	T/200	T/330
Cft/Student	1.00	.75	-.34	.00	-.09	-.26	-.38	-.41	-.38	-.15	-.11	.03	.05	.05	.12	.04	-.17	-.24	-.23	-.26	-.19	.12	-.03	.09	-.06	.04	.03
Cub-Ft	.75	1.00	.30	.03	-.21	-.42	-.44	-.43	-.31	-.03	.04	.11	.25	.21	.06	.16	-.05	-.08	-.08	-.04	.01	-.09	-.15	-.09	-.36	-.08	-.08
No. Students	-.34	.30	1.00	.02	-.08	-.14	.00	.11	.27	.10	.15	.12	.29	.22	-.12	.11	.08	.14	.11	.27	.24	-.36	-.05	-.20	-.28	-.19	-.17
CO2/800	.00	.03	.02	1.00	.28	.24	.20	.24	.35	-.35	-.32	-.17	-.17	-.16	-.08	.28	.24	.25	.13	.33	.51	.28	.04	.00	.24	.23	-.12
CO2/930	-.09	-.21	-.08	.28	1.00	.80	.69	.58	.53	-.30	-.38	-.19	-.19	-.21	-.09	-.39	.07	-.02	-.13	-.07	.07	.36	.25	.34	.39	.33	.27
CO2/1100	-.26	-.42	-.14	.24	.80	1.00	.93	.75	.61	-.42	-.51	-.38	-.41	-.42	-.21	-.46	-.09	-.08	-.04	-.08	-.02	.34	.26	.29	.47	.29	.22
CO2/1230	-.38	-.44	.00	.20	.69	.93	1.00	.82	.68	-.23	-.31	-.15	-.17	-.20	-.17	-.34	-.04	-.03	.10	.04	.12	.13	.12	.22	.43	.35	.12
CO2/200	-.41	-.43	.11	.24	.58	.75	.82	1.00	.86	-.22	-.29	-.10	-.14	-.20	-.14	-.40	-.18	-.23	-.16	-.01	.05	.15	.22	.18	.41	.29	.26
CO2/330	-.38	-.31	.27	.35	.53	.61	.68	.86	1.00	-.22	-.20	-.08	-.11	-.18	-.27	-.23	-.07	-.10	-.01	.10	.20	.07	.30	.25	.32	.26	.27
CaMo/800	-.15	-.03	.10	-.35	-.30	-.42	-.23	-.22	-.22	1.00	.94	.79	.71	.81	.40	.41	.39	.33	.47	.35	.18	-.13	-.29	-.23	-.37	.01	-.03
CaMo/930	-.11	.04	.15	-.32	-.38	-.[illegible]	-.31	-.29	-.20	.94	1.00	.82	.78	.85	.44	.50	.36	.31	.49	.39	.25	-.33	-.31	-.26	-.40	-.04	-.02
CaMo/1100	.03	.11	.12	-.17	-.19	-.38	-.15	-.10	-.08	.79	.82	1.00	.90	.93	.59	.49	.26	.14	.37	.33	.26	-.39	-.28	-.16	-.31	.12	-.08
CaMo/1230	.05	.25	.29	-.17	-.19	-.41	-.17	-.14	-.11	.71	.78	.90	1.00	.94	.53	.39	.26	.15	.31	.28	.29	-.48	-.33	-.20	-.26	.09	-.15
CaMo/200	.05	.21	.22	-.16	-.21	-.42	-.20	-.20	-.18	.81	.85	.93	.94	1.00	.64	.50	.23	.12	.38	.30	.22	-.35	-.23	-.11	-.24	.12	-.11
CaMo/330	.12	.06	-.12	-.08	-.09	-.21	-.17	-.14	-.27	.40	.44	.59	.53	.64	1.00	.30	.00	-.08	.14	.15	-.09	-.15	-.03	-.01	-.04	-.06	.16
RH1/800	.04	.16	.11	.28	-.39	-.46	-.34	-.40	-.23	.41	.50	.49	.39	.50	.30	1.00	.42	.42	.62	.69	.46	-.24	-.29	-.29	-.28	-.14	-.33
RH/930	-.17	-.05	.08	.24	.07	-.09	-.04	-.18	-.07	.39	.36	.26	.26	.23	.00	.42	1.00	.90	.74	.72	.72	-.05	-.51	-.57	-.34	-.36	-.37
RH/1100	-.24	-.08	.14	.25	-.02	-.08	-.03	-.23	-.10	.33	.31	.14	.15	.12	-.08	.42	.90	1.00	.72	.79	.74	-.06	-.48	-.58	-.34	-.37	-.32
RH/1230	-.23	-.08	.11	.13	-.13	-.04	.10	-.16	-.01	.47	.49	.37	.31	.38	.14	.62	.74	.72	1.00	.74	.58	-.15	-.28	-.35	-.39	-.26	-.28
RH/200	-.26	-.04	.27	.33	-.07	-.08	.04	-.01	.10	.35	.39	.33	.28	.30	.15	.69	.72	.79	.74	1.00	.81	-.19	-.38	-.50	-.29	-.36	-.28
RH/300	-.19	.01	.24	.51	.07	-.02	.12	.05	.20	.18	.25	.26	.29	.22	-.09	.46	.72	.74	.58	.81	1.00	-.21	-.43	-.37	-.15	-.12	-.44
T/800	.12	-.09	-.36	.28	.36	.34	.13	.15	.07	-.13	-.33	-.39	-.48	-.35	-.15	-.24	-.05	-.06	-.15	-.19	-.21	1.00	.33	.32	.22	.25	.18
T/930	-.03	-.15	-.05	.04	.25	.26	.12	.22	.30	-.29	-.31	-.28	-.33	-.23	-.03	-.29	-.51	-.48	-.28	-.38	-.43	.33	1.00	.71	.29	.29	.55
T/1100	.09	-.09	-.20	.00	.34	.29	.22	.18	.25	-.23	-.26	-.16	-.20	-.11	-.01	-.29	-.57	-.58	-.35	-.50	-.37	.32	.71	1.00	.41	.60	.30
T/1230	-.06	-.36	-.28	.24	.39	.47	.43	.41	.32	-.37	-.40	-.31	-.26	-.24	-.04	-.28	-.34	-.34	-.39	-.29	-.15	.22	.29	.41	1.00	.51	.05
T/200	.04	-.08	-.19	.23	.33	.29	.35	.29	.26	.01	-.04	.12	.09	.12	-.06	-.14	-.36	-.37	-.26	-.36	-.12	.25	.29	.60	.51	1.00	.19
T/330	.03	-.08	-.17	-.12	.27	.22	.12	.26	.27	-.03	-.02	-.08	-.15	-.11	.16	-.33	-.37	-.32	-.28	-.28	-.44	.18	.55	.30	.05	.19	1.00

31 observations were used in this computation.
One case was omitted due to missing values.

TIME	GROUP MEANS (CO_2)		
	I	II	P-value
1. 8:00	612.5	714.0	0.3025
2. 9:30	1458.4	1657.0	0.5458
3. 11:00	2203.6	2423.5	0.5647
4. 12:30	2401.0	2870.5	0.1283
5. 2:00	2540.3	3517.6	0.0198
6. 3:30	2835.7	4181.0	0.0072

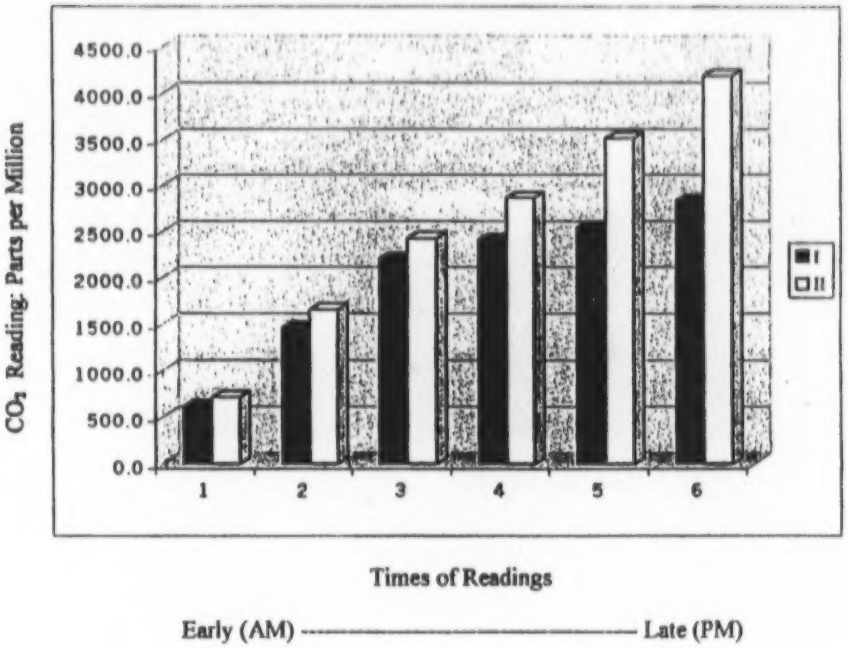

Figure 1. Analyses of CO_2 levels by class size only.

Eliminate School E. Group I is all classes with 17 or fewer students (n=11); Group II is all classes with 19 or more students (n =11). One school was excluded in this analysis for reasons cited in the text.

TIME	GROUP MEANS (CO_2)		
	Large ft^3 VII	Small ft^3 VIII	p-value
1. 8:00	648.8	644.2	.9549
2. 9:30	1183.5	1768.4	.0276
3. 11:00	1735.6	2723.6	.0018
4. 12:30	2250.2	2957.1	.0090
5. 2:00	2499.5	3595.7	.0028
6. 3:30	2757.9	4052.7	.0030

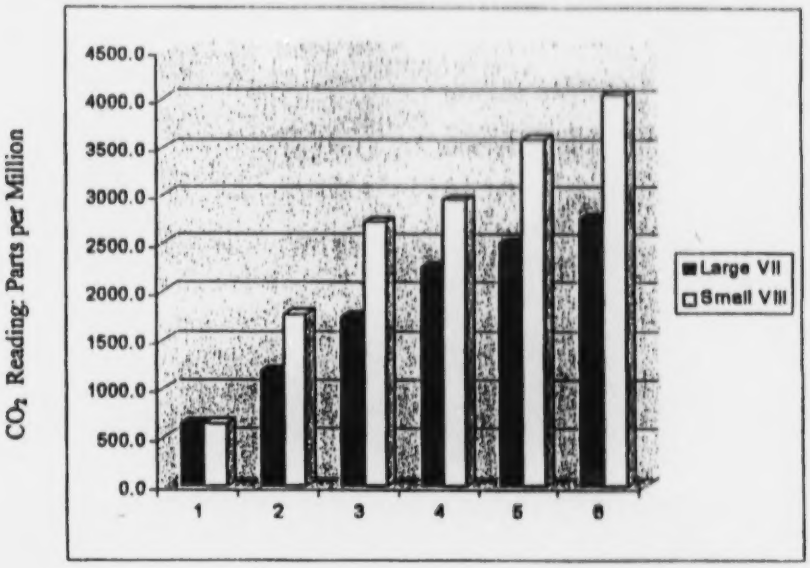

Figure 2. Analysis based on large and small cubic feet (ft^3) feet per student and CO_2 means by time of day.[1]

[1] Eliminate School E. Calculate cubic feet (ft^3)/student. Sort n=27 into large and small number of ft^3/student and compute t-tests/time.

Large (n) = 13 and small (n) = 14 amount of ft^3 /student: t-tests between large (i.e., large number of ft^3/student) and small ft^3/student and CO_2 concentration at time of day.

TIME	GROUP MEANS (CO_2)		
	III	IV	p-value
1. 8:00	632.4	633.2	.9922
2. 9:30	1402.9	1637.9	.4437
3. 11:00	2140.6	2498.3	.3408
4. 12:30	2382.3	2940.0	.0687
5. 2:00	2622.3	3687.2	.0072
6. 3:30	2696.8	4249.3	.0003

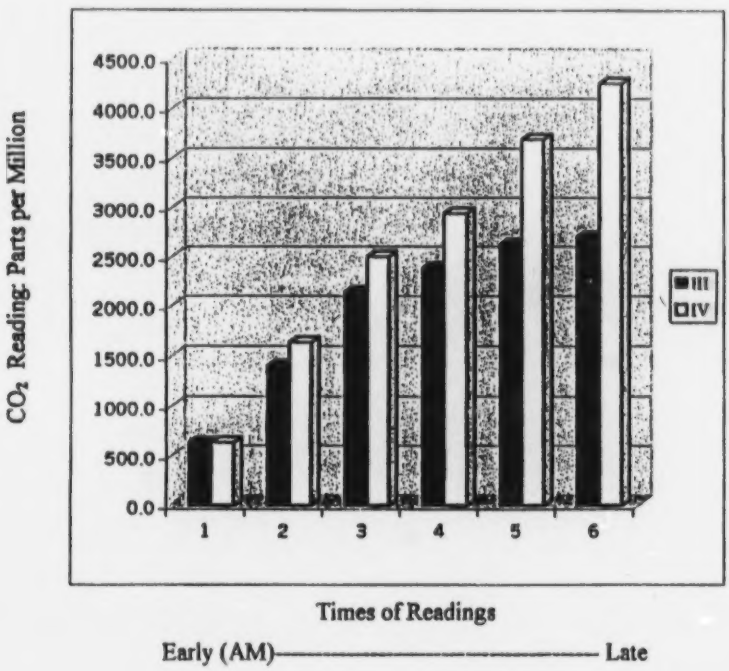

Figure 3. Small and large class comparisons by CO_2 levels using classes within schools.

Group " III " = A2, A5, B3, B4, C1, C5, C6, D3, D4, D6, F1, F2, F4 (Small, n=13)
Group " IV" = A1, A3, A4, B1, B2, C2, C3, C4, D1, D2, D5, F3, F5, F6 (Large, n=14))
School E was eliminated.

Appendix A

A Longitudinal Class-Size Experiment.

Project STAR (1985-1989) and the many studies that build upon STAR (See Table 1 for a partial listing) benefit from the experiment's tightly controlled, in-school longitudinal design. STAR was conducted by a four-university consortium with considerable external support from consultants, advisory groups, and the Tennessee State Department of Education. Basic design issues are:

(1) Project STAR built on principles recognized in prior research. The intervention began in the primary grades. Small classes had fewer than 20 students. STAR's design enabled researchers to look at the effects on minority as well as majority students. Moreover, the design required a "real" difference in the class sizes, from an average of 24 pupils to an average of 15.

(2) STAR was a controlled experiment that permitted, to the extent possible with empirical data, causal conclusions about outcomes. Pupils entering K were randomly assigned to a small class (S; 13-17), a regular class (R; 22-27), or a regular class with a full-time teacher aide (RA). Pupils entering in later years were also assigned at random to classes. Teachers were assigned to classrooms at random. Randomization was monitored carefully.

(3) With minor exceptions, students were kept in their class grouping in grades K, 1, 2, and 3. A new grade-appropriate teacher was assigned to the class each year. STAR was a four-year longitudinal experiment.

(4) Norm-referenced tests (NRT), and criterion-referenced tests (CRT) and measures of self concept and motivation were administered each spring. Researchers used a post-test only design. (Campbell and Stanley, 1963).

(5) The samples were large and diverse. The K year involved over 6300 students in 329 classrooms in 79 schools in 46 districts. The first-grade sample was larger still. The large samples were maintained throughout the four years, producing an excellent longitudinal database. Total sample = 11,601.

(6) The class arrangement was maintained throughout the day, all year long. There was no intervention other than class size and teacher aides. No special training was provided to the teachers except for a small sample in second grade; no special curricula or materials were introduced. (Training didn't increase outcomes).

(7) Students were followed and evaluated after STAR ended in grade 3. Most students graduated in 1998. Their college-entrance test results were monitored. (Krueger & Whitmore, 1999).

APPENDIX B

A Summary of Class-size Findings, and Issues Derived from Various Sources.*

Finding, Idea, Issue, or Question		Selected Sources of Support
I.	Class-size effect was found in all sites, for all participants, at all times and grades K-3, This includes tutoring and "special" projects.	STAR, Challenge, Reading Recovery (RR); Success for All (SFA)
II.	Small classes work best when student starts (K, 1) school in them; they are preventive, not remedial. Compelling research suggests that formal and small-class education MUST start no later than K.	STAR, SSS, Challenge SAGE, Burke Co. Abecedarian (NC), Finn & Achilles (1999)
III.	Crowding, not just small classes, is an issue. School safety and environment are improved. (Prout, In process). School size is related.	STAR, SSS, Nye, Fowler & Walberg, Behavioral Research, Cotton, others.
IV.	Although all pupils benefit from small (S) classes in K-3, some students benefit more than others.	STAR, SFA, RR, LBS, Other class-size work
V.	The teacher is important. Each pupil's learning depends upon the teacher and others in the class. (Thus the class is the unit of analysis).	STAR, LBS, SSS, Challenge, Burke County, CSR in California.
VI.	A teacher aide does not improve student outcomes. This adds to crowdedness and causes new dynamics (Issues: Training, inclusion, ESL, role description).	STAR, Other Studies of Teacher Aides, Finn & Gerber (In process)
VII.	Teachers should use known educational-improvement process: (Parent and home involvement, portfolios, alternative assessments, etc.). Small classes do not change what teachers do—just how much they do good things well.	STAR, LBS, SSS, Filby et al., Burke County, NC Downtown School, NC STAR Teacher Studies.
VIII.	Reduce retention in grade especially when student will be moving into another small class. (Retention should not be used, unless in extreme cases).	STAR, Many studies of Retention (Holmes and Matthews).
IX.	Study costs and benefits; Use PTR and class size differences to get to small classes.	STAR, SSS, PTR studies Darling-Hammond; Miles
X.	Small classes and schools encourage increased student participation in schooling.	Finn, Voelkl, STAR, LBS, Lindsay's work, etc.
XI.	Small classes in early grades provide long-term multiple benefits.	Krueger; STAR Follow-up. Finn & Achilles, etc.

* Detailed references are available. They were omitted from the table because of space and to improve the presentation.

APPENDIX C. Raw Data for the IAQ Study.

ID	Size (n)	Grade	Length	Width	Height	#Occ	CO2_0	CO2_1	CO2_2	CO2_3	CO2_4	CO2_5
A1	318	K	42	25	10	33	577	924	1782	2096	2614	3094
A2	508	2	32	22	13	18	511	1081	1769	2430	3671	2765
A3	444	6	36	22	14	25	514	1654	3396	3769	5013	5360
A4	403	4	24	36	14	30	539	1821	2260	2355	4031	5916
A5	930	1	24	36	14	13	698	1500	2243	2255	3221	3392
B1	428	4	31	23	12	20	1075	1759	2961	2894	3303	3918
B2	728	K-2	68	33	12	37	1156	1556	2148	2498	2367	2047
B3	570	1	23	31	12	15	951	1364	2161	2457	2177	3407
B4	479	6	22	29	12	16	904	1528	2597	2795	2981	3531
C1	581	2	31	30	10	16	457	958	1348	1914	1525	1331
C2	371	4	27	33	10	24	703	1320	1931	2790	3148	3523
C3	496	6	31	32	10	20	638	1229	1546	2223	3489	4201
C4	369	1	28	29	10	22	975	1763	2414	2871	3651	3815
C5	619	K	42	28	10	19	569	825	1277	1671	2150	2320
C6	591	1	28	38	10	18	602	930	1399	2117	2568	2460
D1	516	5	24	43	12	24	371	1161	1722	2609	2305	3189
D2	541	6	43	43	12	41	739	1285	1670	2522	3075	4928
D3	1305	K	43	43	12	17	372	812	1209	1764	1678	2264
D4	687	2	31	24	12	13	709	869	1427	1762	1782	1881
D5	550	3	33	25	12	18	584	1288	1673	2480	2767	2919
D6	690	3, 4, 5	35	23	12	14	716	1757	2517	2773	2907	2950
E1	739	8	32	21	11	10	809	1272	3577	4192	4193	4338
E2	1021	8	29	32	11	10	746	1669	1747	1684	2252	2485
E3	2842	8	58	49	10	10	768	1879	2255	2221	2279	2505
E4	1895	8	58	49	10	15	629	1051	1007	1159	1706	818
E5	540	8	23	32	11	15	2157	2647	3128	3299	4418	6000
F1	383	2	25	23	10	15	546	833	2046	1983	2093	2335
F2	442	5	25	23	10	13	454	1682	3426	3183	3388	3130
F3	404	1	25	25	11	17	459	1231	1789	2278	3487	4113
F4	481	K	25	25	10	13	472	3508	3477	3247	2704	2859
F5	262	7	24	27	10	18	596	1750	3677	3968	4740	4943
F6	284	8	24	26	10	22	567	3755	4828	4949	5698	6000

Appendix C Continued.

ID	CO_0	CO_1	CO_2	CO_3	CO_4	CO_5	RH0	RH1	RH2	RH3	RH4	RH5
A1	1	1	2	2	2	2	31.9	28.4	30.9	32.4	32.8	33.3
A2	2	1	2	2	2	2	26.9	32.1	28.3	28.8	34.7	35.3
A3	1	2	2	2	2	2	34.6	35.8		41.9	44.8	38.1
A4	2	2	2	2	2	2	34.2	38.3	36.2	44.5	45.3	39.6
A5	2	2	2	2	2	3	28.1	28.4	34.8	33.2	35.6	27.4
B1	1	1	1	1	1	1	43.5	46	50.4	50.9	56.3	57.2
B2	1	1	1	2	2	2	41.8	43.1	47.2	47	50.2	51
B3	1	1	1	1	1	1	43.4	44.3	48.8	49.6	50.2	54.6
B4	1	1	1	1	1	1	43.2	44.2	49.7	49.4	51.7	52.3
C1	4	4	3	3	3	3	47.1	49.1	51.6	52.1	52.5	50.1
C2	4	4	4	3	3	3	46.7	49.4	50.1	51 .7	53.7	52.3
C3	4	4	4	3	3	2	47.5	48.6	48.9	50.6	53.4	52.9
C4	4	4	4	3	3	2	45.5	47.7	45.3	48.6	48.2	52.5
C5	4	4	3	3	3	3	43.6	45.1	45.6	48.2	50.5	50.6
C6	4	4	4	3	3	3	43.8	45.9	47.8	49	51.1	52
D1	3	4	3	3	3	2	34.6	35.6	39.1	44.2	39.6	48.2
D2	4	4	3	3	3	1	45.6	44	45.2	48.9	48.2	51.3
D3	4	4	4	3	3	2	42.6	38.9	37.9	50.9	37.7	38.4
D4	4	4	3	2	3	3	68.8	34.9	35.4	47.7	47.7	34.4
D5	5	4	3	3	3	1	38.5	42.2	46.3	45.2	45.7	51.3
D6	5	4	3	2	3	3	35.5	42.7	44.3	54.2	45.4	44.2
E1	1	1	2	2	2	2	39.2	34.2	32.8	52.5	38.4	39.6
E2	1	2	2	2	2	2	35.1	35.3	34.5	34.3	35.4	44.3
E3	1	1	2	2	2	2	34.3	37.4	37.1	35.7	37.8	37.9
E4	2	2	2	2	2	2	35.6	38.1	35.5	38.3	37.2	44.3
E5	1	1	2	2	2	2	41.1	43.7	43.5	42.1	45.5	58.9
F1	2	2	0	1	1	1	26	46.7	46.8	47.1	35.8	34.7
F2	2	1	1	1	1	1	23.5	36.5	42.8	36.4	36.8	36.9
F3	2	2	1	1	1	1	23.3	32.3	32.3	31.8	32.3	33.1
F4	2	1	2	2	2	2	24	45.8	41.3	42.6	33.8	36.1
F5	2	2	2	2	2	2	23.8	34.4	34.8	41 .2	42.3	44.8
F6	2	2	2	2	2	2	24.4	37.5	38.1	41 .2	44.1	45.2

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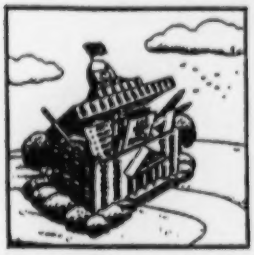
Appendix C Continued.

ID	T0	T1	T2	T3	T4	T5
A1	68.9	74.1	74.2	73.7	73.8	71.2
A2	68.7	71.9	71.9	72.4	72.6	72.8
A3	70.3	72.1		70.8	70.6	72
A4	69.6	74.3	73.6	70.6	70.7	75.9
A5	70.4	74.4	72.1	73.3	73.8	80.2
B1	69.8	73.2	71.1	71.3	72	73.6
B2	70.1	69.5	69.9	69.7	71.7	71.7
B3	70.1	71.4	72.4	72.3	72.3	72.2
B4	69.4	71.5	71.3	71.4	72.3	73.5
C1	67.5	69.5	71.3	71.4	71.6	71.7
C2	68	69.9	70.4	70.8	72	73.4
C3	68.1	69.6	69.7	71.7	72.7	71.8
C4	68.7	70.1	70	70.9	73	73.5
C5	69.2	69.8	70	71.4	71.6	72
C6	69	70.2	70.8	71.3	72.3	72.4
D1	63.9	71.5	72.9	72.6	73.5	74.3
D2	68.7	71.3	71	71.8	73.3	72.8
D3	69.1	71.6	73.1	65.6	73.7	74.2
D4	70.8	72.5	73.6	73.4	73.9	74
D5	71.9	72	73.1	73	74.7	72.8
D6	73.3	73.5	73.1	71.3	72.8	74.2
E1	68.9	71.7	72.3	75.2	73.6	71.7
E2	70.2	72.2	72.6	72.4	72.5	73.1
E3	70.8	71.4	72.2	73.2	72.6	73.2
E4	70.2	71.4	73.1	72.8	73.7	73.3
E5	72	72.3	74.1	75.2	75.5	73.2
F1	71.3	72.4	71.3	71.8	72	73.3
F2	71.4	69.7	71.7	72.5	72.7	73.1
F3	70.7	70.8	71.9	72.6	73.1	74.6
F4	71.3	72.5	73.2	74.1	73.9	74.2
F5	70.9	72.4	73.5	73.8	74.1	75.1
F6	70.4	72.5	74	74.1	74.3	74.8

18A

IAQ Backgrounder



Good indoor air quality contributes to a favorable learning environment for students, productivity for teachers and staff, and a sense of comfort, health, and well-being for all school occupants. These combine to assist a school in its core mission – educating children.

The goal of the Checklist is to provide clear and easily applied activities that you can use to help prevent indoor air quality problems and resolve any problems promptly if they do arise. Once you understand the basic principles and factors that influence indoor air quality in your school, you will note that the specific activities involve two major actions — the management of pollutant sources, and the use of ventilation for pollutant control. This guidance is based on the following principles:

- Many IAQ problems can be prevented by school staff and students
- When IAQ problems do arise, they can often be resolved using the skills of school staff
- The expense and effort required to prevent most IAQ problems is much less than the expense and effort required to resolve problems after they develop

Why IAQ is Important to Your School

Most people are aware that outdoor air pollution can damage their health, but many do not know that indoor air pollution can also have significant harmful effects. U.S. Environmental Protection Agency (EPA) studies of human exposure to air pollutants indicate that indoor levels of pollutants may be 2-5 times, and occasionally more than 100 times, higher than outdoor levels. These levels of indoor air pollutants may be of particular concern because it is estimated that most people spend about 90% of their time indoors. Comparative risk studies performed by EPA and its Science Advisory Board have consistently ranked indoor air pollution among the top five environmental health risks to the public.

Failure to prevent indoor air problems, or failure to respond promptly, can have consequences such as:

- increasing the potential for long term and short term health problems for students and staff
- impacting the student learning environment, comfort, and attendance
- reducing productivity of teachers and staff due to discomfort, sickness, or absenteeism
- accelerating deterioration and reducing efficiency of the school physical plant and equipment
- increasing the potential that schools will have to be closed, or occupants temporarily relocated
- straining relationships among school administration and parents and staff
- creating negative publicity that could damage a school's or administration's image and effectiveness
- creating potential liability problems

Indoor air problems can be subtle and do not always produce easily recognized impacts on health, well-being, or the physical plant. Children may be especially susceptible to air pollution. For this and the reasons noted above, air quality in schools is of particular concern — proper maintenance of indoor air is more than a "quality" issue, it encompasses safety and stewardship of our investment in the students, staff, and facilities.

Understanding IAQ Problems and Solutions

Over the past several decades, exposure to indoor air pollutants has increased due to a variety of factors, including the construction of more tightly sealed buildings, reduced ventilation rates to save energy, the use of synthetic build-

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ing materials and furnishings, and the use of chemically-formulated personal care products, pesticides, and housekeeping supplies. In addition, our activities and our decisions, such as deferring maintenance to "save" money, lead to problems from sources and ventilation.

Four basic factors affect IAQ: sources of indoor air pollutants, heating, ventilation, and air-conditioning (HVAC) system, pollutant pathways, and occupants.

Sources of Indoor Air Pollutants

Indoor air contaminants can originate within the building or be drawn in from outdoors. If pollutant sources are not controlled, IAQ problems can arise, even if the HVAC system is properly operating. Air pollutants consist of numerous particulates, fibers, mists, bioaerosols, and gases. It may be helpful to think of air pollutant sources as fitting into one of the categories in the table shown below.

In addition to the number of potential pollutants, another complicating factor is that indoor air pollutant concentration levels can vary by time and location within the school building, or even a single classroom. Pollutants can be emitted from point sources, such as from science store rooms, or from area sources, such as newly painted surfaces, and pollutants can vary with time, such as only once each week when floor stripping is done, or continuously such as fungi growing in the HVAC system.

Typical Sources of Indoor Air Pollutants

Outside Sources	Building Equipment	Components/Furnishings	Other Indoor Sources
Polluted Outdoor Air • pollen, dust, fungal spores • industrial emissions • vehicle emissions **Nearby Sources** • loading docks • odors from dumpsters • unsanitary debris or building exhausts near outdoor air intakes **Underground Sources** • radon • pesticides • leakage from underground storage tanks	**HVAC Equipment** • microbiological growth in drip pans, ductwork, coils, and humidifiers • improper venting of combustion products • dust or debris in ductwork **Non-HVAC Equipment** • emissions from office equipment (volatile organic compounds, ozone) • emissions from shops, labs, cleaning processes	**Components** • microbiological growth on soiled or water-damaged materials • dry traps that allow the passage of sewer gas • materials containing volatile organic compounds, inorganic compounds, or damaged asbestos • materials that produce particles (dust) **Furnishings** • emissions from new furnishings and floorings • microbiological growth on or in soiled or water-damaged furnishings	• science laboratories • vocational arts areas • copy/print areas • food preparation areas • smoking lounges • cleaning materials • emissions from trash • pesticides • odors and volatile organic compounds from paint, caulk, adhesives • occupants with communicable diseases • dry-erase markers and similar pens • insects & other pests • personal care products